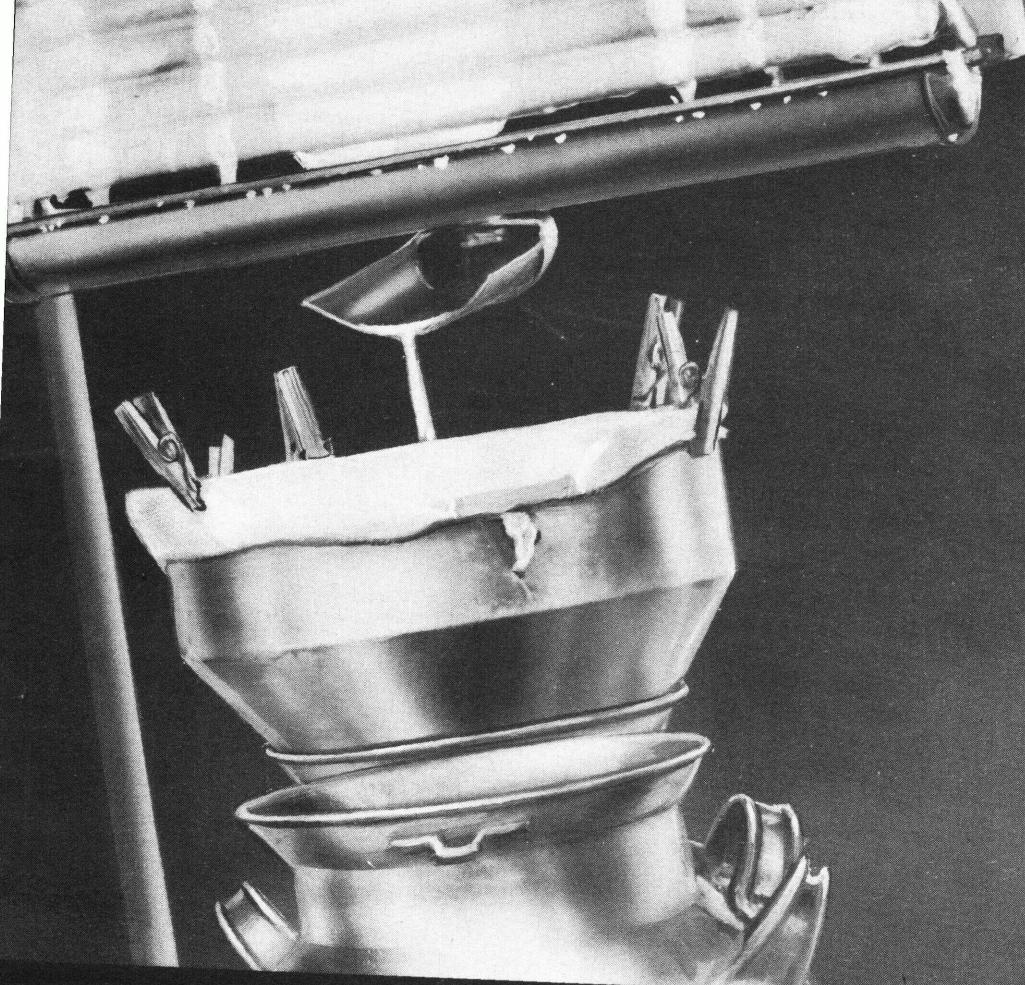


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MECHANICAL MILK COOLING ON FARMS



FARMERS' BULLETIN No. 1818

U. S. DEPARTMENT OF AGRICULTURE

THE INCREASED DEMAND for high-quality milk by consumers and the increasingly strict requirements of local and State health departments in regard to the production and handling of milk have led to a great increase in the use of mechanical refrigeration on dairy farms. Although ice, if available in sufficient quantities, will cool milk and hold it at sufficiently low temperatures, it lacks the advantage of automatic operation to be had with electrically driven milk-cooling units or semiautomatic in the case of most other power units.

The increase in the percentage of farms served with high-line electricity from 2.7 percent in 1924 to 17.5 percent in 1937 has stimulated the use of electric refrigerating outfits.

To save useless expense, a refrigerating machine with its storage tank or box should be large enough to take care of the greatest daily production of milk but no larger. The refrigerating unit itself should be large enough to supply the total amount of refrigeration needed each day in from 10 to 12 hours of operation.

No amount of refrigeration, however, will take the place of care in cleaning the barn, the milk room, and the utensils used in handling the milk. Refrigeration merely keeps the milk in its original state; it does not eliminate bacteria.

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MECHANICAL MILK COOLING ON FARMS

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INTRODUCTION

M ECHANICAL REFRIGERATION for cooling and storing milk on farms has increased rapidly in recent years. There are now on the market many small refrigeration machines suitable for use where electric power is available. Where electric power lines are not found, refrigerating units may be powered by gasoline motors. Some units using kerosene for power are also available. These machines can be obtained, with or without the storage unit, in sizes suitable to any dairy farm.

To obtain definite information on what dairy farmers in general may expect from small refrigerating machines, a study was made at 44 dairy farms in Maryland and Virginia where electric cooling outfits of various types were in use. The amount of milk handled ranged from 15 to 200 gallons per day per farm. The study covered methods of arrangement and operation, power consumption, cost of equipment and repairs, and efficiency of the different outfits in comparison with each other. The results obtained on these farms have already been given in Circular 336, Cooling Milk on the Farm with Small Mechanical Outfits. These results, along with observations of methods, and equipment used in representative dairy sections of the country east of the one hundredth meridian, are presented and discussed in this bulletin, with suggestions for effective arrangement and operation. Plans are also included for an inexpensive home-made storage tank and a refrigerator box. Such a tank or box, if properly constructed, is as efficient as a factory-built tank and is often cheaper.

COOLING DELAYS CHANGES

As drawn from the udder, milk is an ideal food for many kinds of bacteria, and its temperature is right for their rapid development. Unless bacterial growth is checked, undesirable changes may take place in the milk causing off flavors and odors or souring. Cold is the chief factor used on the farm to prevent the growth of bacteria in milk.

For example, in one experiment milk with a bacterial content of 16,000 per cubic centimeter kept sweet for about 36 hours when held at a temperature of 75° F., 80 hours when held at 55°, and 180 hours when held at 40°. Bacterial off flavors may develop at any temperature, but they develop more rapidly at the higher temperatures. In other words cooling delays changes in the milk which affect quality and palatability and helps to maintain its original quality. High-quality milk doubtless helps to increase and stabilize the market for milk. Therefore it is of the utmost importance that milk be promptly cooled to and stored at a temperature of 50° or lower.

No means of cooling milk will offset carelessness in production and handling. The same attention to sanitation should be given when mechanical refrigeration is used as is necessary with any other means of cooling.

THREE MEANS OF COOLING MILK

On farms milk is cooled in one of three ways—by water, ice (either natural or artificial), or mechanical refrigeration.

Water from wells, springs, or supply tanks, even under the best conditions, is usually not cold enough to cool the milk below 50° F. in warm weather. There are difficulties in using water alone in storing milk, so that its use is limited to sections where a large supply of cold water can be used without fear of water shortage. The use of ice or mechanical refrigeration is therefore resorted to for cooling and storing milk on most farms during warm weather in order to get temperatures low enough to control bacterial growth. Where ice is employed on the farm for cooling and storing milk, a tank in which ice and water form the cooling medium is generally used. This type of storage is known as the wet tank. On producer-distributor farms where milk is bottled, dry-box storage with ice as the cooling medium may be used, but on other types of farms this system is not so practical.

The use of water and of ice for cooling milk on dairy farms is discussed more fully in Farmers' Bulletin 976, Cooling Milk and Cream on the Farm.

Either wet-tank or dry-box storage can be operated economically with mechanical units. Where wet storage is used with mechanical units, the evaporating coil¹ for absorbing the heat is placed in the water in the storage tank. Where dry storage is used, the cooling medium is usually a brine solution confined in an iron or copper tank within the storage box. The evaporating coil is located in the brine tank, and by absorbing heat from the brine keeps it chilled. In wet storage there are only two transfers of heat, namely, from the milk to the water in the storage tank, and from the water to the coils; whereas in dry storage there are three transfers of heat; that is, from the milk to the air in the box, from the air to the brine solution, and from the brine to the coils. The extra heat transfer along with the fact that air is not so efficient as water in transferring heat, makes the operating cost of dry-box storage higher than that of wet-tank storage. The average amount of electric power used to cool 1 gallon of milk 1° F. on 27 farms having wet tanks was 4.6 watt-hours, and on 7 farms having dry boxes it was 5.8 watt-hours.

¹ So-called because in it the refrigerant is permitted to evaporate in order to absorb heat from the surrounding water or air (p. 3).

WHY MECHANICAL COOLING IS INCREASING

The rapid increase in the use of refrigerating machines on dairy farms is due chiefly to (1) improvement in the machines, (2) the extension of electrical lines into the country and reduced cost of electricity, (3) irregular deliveries of ice, (4) saving in labor, and (5) regulations of health departments.

Manufacturers of refrigerating machinery have made great progress in recent years in developing the small self-contained compression machines which are almost universally used for small-scale mechanical refrigeration. The principal parts of such an outfit are the compressor and motor, condensing coils, evaporating or cooling coils, and the storage tank or box. In these machines much improvement has been made in the compressor, the expansion valve, and thermostatic or pressure temperature controls.

The rapid extension of electrical lines into the country has made the use of electric refrigerating machines possible on many farms. In 1924 only about 2.7 percent of the farms in the United States were served with high-line electricity; in 1932, 11 percent; in 1937, 17.5 percent; and in 1946, 52.9 percent.

In sections where farmers use manufactured ice, irregularity of delivery has turned many to the use of refrigerating machines. A long period of farm-labor scarcity following 1917 and 1941 was also a factor in bringing more of them into use.

Health-department regulations also have helped to bring about a change in refrigerating methods. In most markets over which public-health authorities have control it has been the practice to set a maximum temperature for the milk when it reaches the city market. The temperature requirements are becoming more rigid all the time, and in some cities the maximum allowable temperature is as low as 40° F. Although these temperatures can be attained with ice, an abundant supply must be present at all times. The ice takes up extra room in the tank, and the dairyman must keep a watchful eye to see that the amount is sufficient to maintain the required temperature. Mistakes in judging the right amount of ice may lead to poor-quality milk.

TYPES OF REFRIGERATING MACHINES

The refrigerating machines observed under actual working conditions and discussed herein were compression machines, all driven by electric or gasoline motors. All machines worked on the same principle, although sulphur dioxide, methyl chloride, or ammonia were used as refrigerants in different machines. These machines cool by alternately vaporizing and condensing a volatile liquid. Ammonia, sulphur dioxide, methyl chloride, and similar volatile liquids evaporate at ordinary room temperatures when not under pressure, but condense again into liquid form on being compressed and again cooled to room temperatures. The liquid is permitted to evaporate in the coil in the brine or cooling tank, and in doing so it absorbs heat from the surrounding water or air. The gas is then compressed, cooled by the air or water circulating around the condensing coils, and becomes a liquid. It is then in condition to be evaporated again, and absorb more heat from the tank or box.

COST OF OUTFITS

The cost of outfits was obtained on 50 farms. On 38 of these farms a complete outfit had been purchased, including the mechanical unit (compressor, condenser, and motor), a manufactured cooling tank or box, coils, and a circulating pump with its motor or an agitator. In this group the cost of the complete outfit per cubic foot of storage capacity averaged \$15.14 and ranged from \$10.40 to \$30.50 per cubic foot. Twenty-four outfits, or 63 percent of those in this group, cost between \$10 and \$15 per cubic foot, and 10 outfits, or 26 percent, cost between \$15 and \$20 per cubic foot.

In 11 cases no tank or box was purchased with the outfit, and the cost of the tank or box was not obtained. For this group the average cost of the mechanical outfit per cubic foot of storage space was \$13.30, with a range from \$8.80 to \$21.20. For eight plants, or 73 percent of this group, the cost was between \$8 and \$15 per cubic foot of storage.

In table 1 the cost of the complete outfits is figured on the basis of the rated storage capacity in 10-gallon cans. It is interesting to note that the average price per outfit shows a decrease of from 1 to 50 percent between 1928-31 and 1933-37.

TABLE 1.—*Cost of 38 mechanical milk-cooling outfits,¹ arranged according to rated storage capacity, for the years 1928-31 and 1933-37*

Farms (number)		Rated storage capa- city ²	Price range (com- plete outfit)		Average price		
			1928-31	1933-37	1928-31	1933-37	1928-31
1928-31	1933-37	10-gallon cans	Dollars	Dollars	Dollars	Dollars	Dollars
7	3	4	350-500	185-220	410	208	103
7	7	6	328-700	350-450	481	389	80
6	3	8	485-635	450	554	450	69
2	2	10	510-550	495-550	530	523	53
1	-----	14	675	-----	675	-----	48

¹ 23 of these outfits were purchased during the period 1928-31 and 15 between 1933 and 1937.

² Number of 10-gallon cans that can be placed in the tank at one time.

COST OF REPAIRS

The cost of repairs over periods of from 3 months to 9 years was obtained on 44 farms. The machines had an average age of 2 years 8 months. The average cost for repairs was \$3.60 a year. Of this group, 27 machines that had been in use from 1 to 9 years, on an average 3 years 4 months, cost \$4.70 a year, and 17 machines ranging from 3 months to 4 years in age and averaging 1 year 7 months had required no service at all. Repairs were various, the more common being the regulation of the temperature control, replacing belts, repairing leaks, and adding new refrigerant to replace that lost by leakage. In one case the compressor valves had to be replaced, and in two others motors had to be traded in on new motors or repaired. Some sales firms have a flat yearly service charge for which a repairman will take care of all repair work. The owner generally pays for new parts.

INSTALLATION AND ARRANGEMENT**LOCATION OF THE MACHINE**

Mechanical cooling units are usually installed in one of three locations—in the room with the milk-storage tank or box; in a separate room (fig. 1); or outside the milk house, the machine being protected under a shed with lattice work on the sides (fig. 2.)

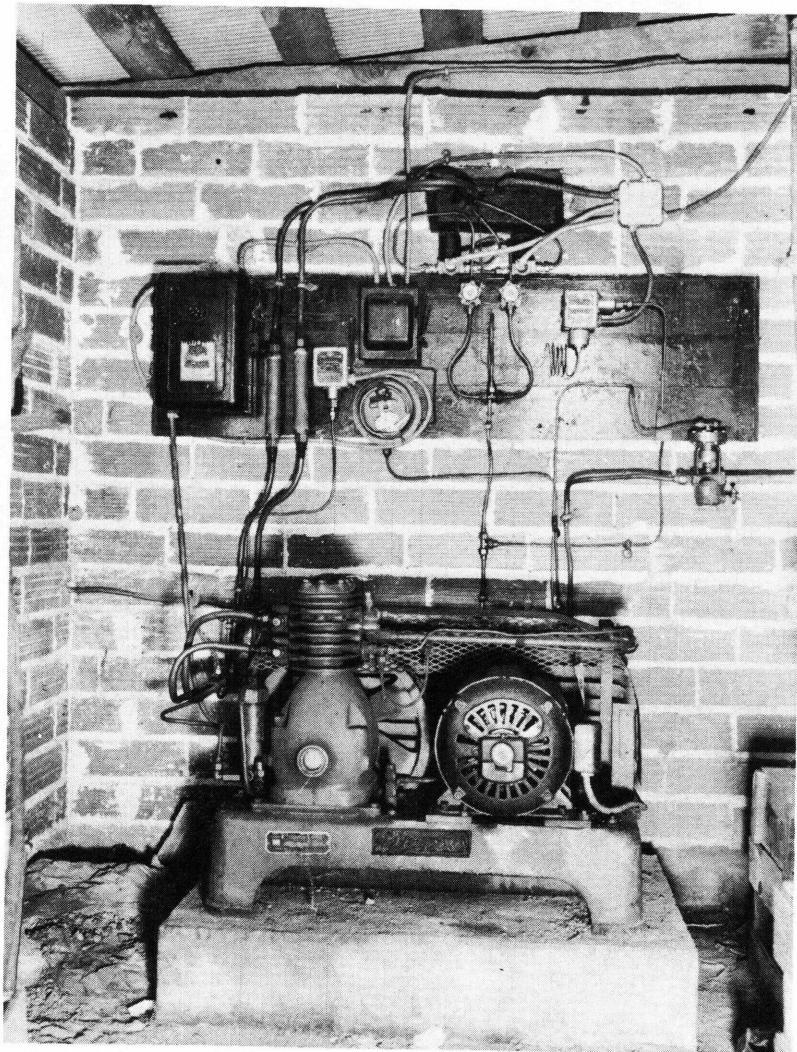


FIGURE 1.—A compressing unit in a separate room. All the controls are mounted on a panel readily accessible for inspection and care.

These machines should be located in a well-lighted, well-ventilated room separate from the storage or milk-handling room. Nearly all of them are air-cooled, and they tend to circulate dust and to pull it in from outside where the screened opening is provided for ventilation.

If the machine is in the milk room, some of this dust is likely to come in contact with the milk or the utensils. Another objection to having the machine in the milk room is that it generates heat, which at times may raise the air temperature of the room more than 6° F. The machine must not only overcome this additional heat in cooling the

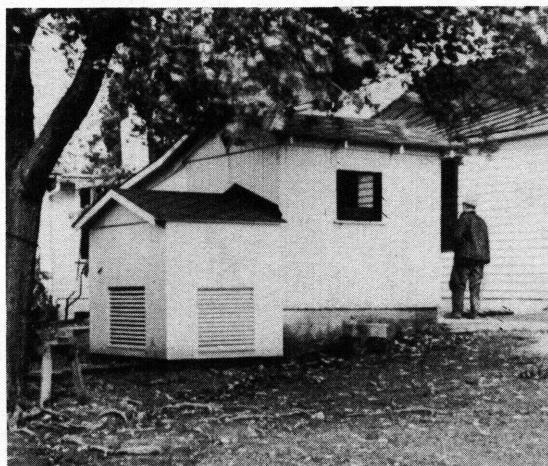


FIGURE 2.—A small shed with latticework sides built next to the milk room to house the compressing unit.

milk but also work at a higher temperature, which reduces the efficiency of the condensing unit. The machinery needs oil, and except in the case of hermetically-sealed units it is hard to use oil without dropping some. The older the machine, the more oil leaks out. The dark area in figure 3 is the result of leakage of oil. Machines of this

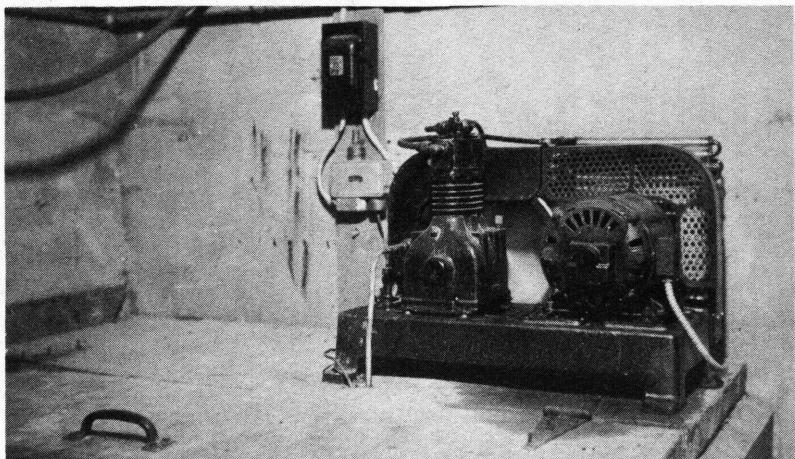


FIGURE 3.—Cooling unit on top of storage box. The dark area on the top of the storage box is oil from the machine.

kind should not be placed in a milk room—most certainly not on top of the storage tank.

POWER FOR ELECTRIC-DRIVEN MACHINES

The voltage of power lines supplying farms in the past has been variable. That of the lines furnishing power to the farms where actual tests were made fluctuated greatly, but no cases of injury to motors or equipment due to high or low voltage were observed. However, all equipment should be properly protected by fuses and "inverse-time" protective devices. In most instances the line voltage was low at milking time because of the heavy load thrown on the line at that time by refrigerators, milkers, lights, hot-water heaters, and ranges. On one farm the motor of the refrigerating unit would not start when the electric range was in use. This trouble was found to be due to a too-light service connection rather than to low voltage in the power line. Care should be taken therefore to have the service entrance lines and the wire supplying current to the outfit of sufficient size to eliminate any appreciable line drop and low voltage. Most power companies have trained field representatives to advise the consumer of the proper installations for his individual needs. Electric service is now generally good and free from interruptions.

SIZE OF COMPRESSOR REQUIRED

Theoretically 0.056 pound of ice-melting capacity, or the melting-ice equivalent, as it is known in refrigeration, is required for 1 gallon-degree of refrigeration of 4-percent milk; that is, to cool 1 gallon of 4-percent milk 1° F. Since in a well-constructed storage box used to capacity the milk cooling load is equal to 70 percent of the refrigeration load and the heat loss is 30 percent, the refrigeration required per gallon-degree in ice-melting capacity, would be 0.08 pound.³ The capacity of the compressor needed can be found as follows: Multiplying the number of gallons of milk to be cooled per day by the number of degrees it is to be cooled by the refrigerating machine gives the total number of gallon-degrees; then multiplying the number of gallon-degrees by 0.08 gives the total ice-melting capacity needed per day. Dividing this amount by the number of hours the machine is to run each day (for example 12 hours) will give the rating of the compressor needed, in pounds of ice-melting capacity or melting-ice equivalent per hour. Table 2 gives the data for a 10-gallon can of milk when cooled from 10° to 60° F.

TABLE 2.—*Total refrigeration required per day per 10-gallon can of milk to be cooled to and stored at 40° F. and the compressor capacity per hour needed to furnish that refrigeration in 12 hours*

Range of cooling temperature ($^{\circ}$ F.)	Melting-ice equivalent ¹ —		Range of cooling temperature ($^{\circ}$ F.)	Melting-ice equivalent ¹ —	
	Per day of refrigeration ²	Per hour of compressor rating		Per day of refrigeration ²	Per hour of compressor rating
	Pounds	Pounds		Pounds	Pounds
10.....	8	0.7	40.....	32	2.7
20.....	16	1.3	50.....	40	3.3
30.....	24	2.0	60.....	48	4.0

¹ These figures can be converted to British thermal units by multiplying by 144.

² This column gives the approximate amount of refrigeration or ice-melting capacity required each day of 24 hours and should not be confused with the capacity of a refrigerating machine necessary to furnish this amount of refrigeration in 12 hours' running time.

³ For a tank or box that is poorly insulated or too large for the quantity of milk to be cooled, more than 0.08 pound will be required.

The capacity of compressor needed for cooling and storing any amount of milk can be computed readily by multiplying the figures given in table 2 by the maximum number of 10-gallon cans of milk to be cooled. The figures given under refrigeration required per day represent the total amount of ice required to cool and store 10 gallons of milk, while the compressor rating represents the capacity of compressor needed, if it is to run 12 hours per day.

To show the approximate size of motor required to drive a compressor suitable to handle the cooling load in 4-, 6-, 8-, 10-, and 12-can tanks when cooling and storing that number of 10-gallon cans of milk per day, table 3 was prepared. It is based on average efficiencies of equipment and on the actual sizes of motors used to cool such tanks over the central, southern, and eastern parts of the United States.

SIZE OF STORAGE TANK OR BOX

Table 4 is based on average efficiencies and gives the approximate sizes of refrigerating units, motors and brine tanks to cool different quantities of milk through a 60° temperature range and to cool the proper size of box to store it at an average box temperature of 40° F. The average daily temperature of the air surrounding the box was taken as 85° F. This is considered the maximum temperature that need be used. Greater temperatures that may be encountered in a few localities will be taken care of by a small increase in running time. If well or spring water is used to pre-cool the milk the running time of the compressor will be reduced, and in boxes designed for 300 quarts or more this reduction may be large enough to require the use of the next smaller size of refrigerating unit. Where cool soft water is available units with water-cooled condensers are more efficient than those with air-cooled condensers when the average air temperatures are high. Water that forms much scale in boilers makes it necessary to clean the condenser coils at regular intervals and the inconvenience thus caused overcomes the advantages of water-cooled condensers.

It is important that the storage tank or box be of the proper size for the amount of milk to be handled. A good general rule is to buy a size sufficient to care for the maximum daily quantity of milk produced at any season of the year, and no larger. The economy of this practice is shown by table 5 where the power requirements to maintain the temperature in an eight-can storage tank alone and with different cooling loads is given.

The correct size for the storage tank depends on the method of handling the milk. In some localities the morning's milk does not have to be cooled if it is delivered to the country receiving station by a certain time. Where the morning's milk is cooled the evening's milk is sometimes set out of the cooling tank and stands on the milk room floor until the morning's milk has been cooled and both lots are loaded. This practice may lower the quality of milk and where there is a long haul the milk temperature may go above market requirements. Another practice is to cool and store the evening's milk and to cool the morning's milk over a milk cooler only. This is a good method where proper sanitation is observed and local milk regulations do not prohibit the use of such equipment.

TABLE 3.—*Approximate capacity of compressor and size of electric motor¹ necessary to cool and store different quantities of milk a given number of degrees of temperature, if the motor runs 12 hours a day*

Approximate length of $\frac{1}{2}$ -inch copper tubing for coil

¹ Gasoline motors are not so efficient as electric motors nor are they made in as small sizes. Most compressors of the sizes given in this table are driven by 1½ or 2-horsepower gasoline motors.

² M. I. E. = melting-ice equivalent, which can be converted to British thermal units by multiplying by 144.

³ The length of cooling coils needed depends on many factors, such as the refrigerant, its operating temperature and pressure, and the temperature desired in the storage medium. The manufacturer's recommendation for length of coils should be obtained. See p. 14.

TABLE 4.—*Size of storage boxes, their equipment and operation necessary to cool milk 60° F. and store it in bottles if the average storage temperature is 40°, the air temperature is 85°, and the coefficient of heat transfer through the walls of the box is 2 B. t. u. per square foot per degree temperature difference per 24 hours*

Capacity of box.....	quarts.....	200	300	400
Size of refrigerated space.....	feet.....	3 x 4 x 6	4 x 6 x 7	6 x 6½ x 7
Size of brine tank required.....	do.....	2 x 3 x 2½	3 x 1½ x 5	5 x 1¾ x 4
Brine required.....	gallons.....	107	161	222
Vertical tank surface required ¹	square feet.....	25	41	53
Size of compressor.....	m. i. e. ² , pounds per hour.....	22	42	61
Size of motor.....	horsepower.....	½	1	1½
Operating time.....	hours.....	13	11	10

¹ When the vertical tank surface is less than required, vertical fins must be added to the tank.

² See footnote 2, table 3.

TABLE 5.—*Approximate power requirements per day for an 8-can storage-tank outfit when used for cooling and storing different quantities of milk¹*

Item	To keep tank cool	To cool—				
		4 cans; store 2 cans	8 cans; store 4 cans	10 cans; store 5 cans	12 cans; store 6 cans	16 cans; store 8 cans
Total.....	Watt-hours.....	3,627	5,719	7,811	8,837	9,903
Per can.....			1,430	976	886	750

¹ These figures are based on an average outside temperature of 80° F. and an average storage-tank temperature of 40°. An analysis of the data used in arriving at these figures is given in Circular 336, Cooling Milk on the Farm With Small Mechanical Outfits.

Where both night's and morning's milk are placed in the cooling tank or when milk production varies, the cooling tank is sometimes divided into two sections by a dividing wall as high as the desired water level. A pump is used to circulate the water from one section to the other. After one division has been pumped full, the water overflows the dividing wall and goes back into the compartment having the lower water level. This system not only keeps the water level constant around the cans but also provides for circulating the water and thus cooling the milk more quickly.

LOCATION OF THE BRINE TANK IN STORAGE BOX

A number of the outfits studied had dry-storage boxes. When this type of storage is used with a refrigerating machine on the dairy farm, the most advantageous location of the brine container or tank is at the top of the storage box (fig. 10). Either copper, galvanized iron, or boiler plate may be used for constructing the brine tank; the last is probably the cheapest. If boiler plate is used, apply a protective coat of red lead. If the evaporating coils are of copper, a copper tank is probably more satisfactory, as having only the one kind of metal eliminates electrolysis, which causes corrosion.

The brine can be made either of sodium chloride (common salt) or calcium chloride. The latter is generally used, as it has a lower freezing temperature with the same concentration. The quantity of brine required in the tank depends on the quantity of milk to be cooled daily, the desired cooling temperature, and the size and insulation of the box. However, as a general rule, with calcium chloride brine, there should be about 1½ to 2 gallons of brine in the tank per gallon

of milk cooled per 24 hours. In making up the brine, $2\frac{1}{2}$ pounds of calcium chloride, with 1 ounce of lime for preventing electrolysis, should be added to each gallon of water. The average temperature of the brine usually used on dairy farms is 20° to 25° F.

Where gasoline motors are to be used, allowance must be made for differences in the sizes of available motors and their efficiency. Since gasoline-motor-driven units are, as a rule, not automatic in operation, the unit is run only twice a day for from 2 to 8 hours at milking times. For this reason the compressor is often larger than those used to do the same work when driven by electric motors.

THERMOSTATIC CONTROL IN THE STORAGE

To maintain a nearly constant temperature in the storage tank or box, electrically operated machines are generally equipped with a thermostatic control. This device starts and stops the machine automatically whenever the temperature in the box or tank varies a few degrees above or below the desired temperature.

In a dry box such controls can be located at a height where they will be protected from mechanical injury. Except in very large units the temperature at the ceiling in a well-constructed dry box should not be more than 2° or 3° higher than at the floor. Such a small difference can be taken care of by the setting of the thermostat. For instance, if it is necessary to place the control near the top of the box to protect it from mechanical damage and a temperature of 33° is desired at the average storage height, the thermostat can be set at about 35° .

A mechanical unit to cool a dry storage box for handling bottled milk should have enough capacity to cool the bottles and crates as well as the milk. The average cooling load for bottles and crates alone with the milk-room temperature at 80° F. is approximately 1.4 pounds of melting-ice equivalent for each gallon of milk. The following example shows how to figure the cooling load on a farm where 100 gallons of milk a day are cooled and bottled if the milk is cooled to 40° by refrigeration and the milk-room temperature is about 80° F.

The refrigeration required per day per 10-gallon can is 32 pounds of melting-ice equivalent (table 2). Then 10 multiplied by 32 gives 320 pounds to cool and store 100 gallons. The cooling load for bottles and crates would be 100×1.4 , or 140 pounds of melting-ice equivalent. The total load would be 320 plus 140, or 460 pounds of melting-ice equivalent. Since this refrigeration should be furnished in about 12 hours the capacity of the compressing unit should be 38.33 pounds of melting-ice equivalent per hour (460 pounds divided by 12) or 920 pounds of melting-ice equivalent per day (24×38.33).

In wet tanks equipped with some means of agitation the thermostatic-control bulb can be located at almost any point along the refrigeration coils since the temperature varies little throughout the tank. The bulb must be covered with water at all times. If tank water is pumped through a milk cooler, agitation of the water in the tank will be unnecessary. The milk will be cooled quickly below 50° F. before being placed in the tank and the circulation of the storage water through the cooler will give some agitation in the tank. A test of arrangements of cooler intake and outlet shows that the intake should be as far as possible from the thermostatic control and the cooler outlet over the control. Where there is a tendency for too much ice to freeze on the coils the cooler return can be extended along

the coils with a length of pipe having a row of small holes in its under side to distribute the warm water over the coils.

AGITATION OF WATER IN STORAGE TANKS

Where milk is strained directly into cans and placed in the tank to be cooled from near body temperature to below 50° F. the water should be agitated. The movement of the water not only keeps its temperature almost even throughout but also removes the heat from the milk in a shorter time. Tests show that the temperature of all the milk in a 10-gallon can will be reduced to 50° or below in 1 hour or less if the water is thoroughly agitated, sufficient refrigeration is supplied, and a milk to water ratio of 1 to 1½ or more is used. Without agitation it may require 7 or 8 hours, depending on the initial water temperature, the refrigeration available, and the water to milk ratio. The water can be moved in several ways. In some cases a propeller is mounted on the end of a shaft and connected to a vertical motor placed on top the cooling tank (fig. 4). In other tanks the

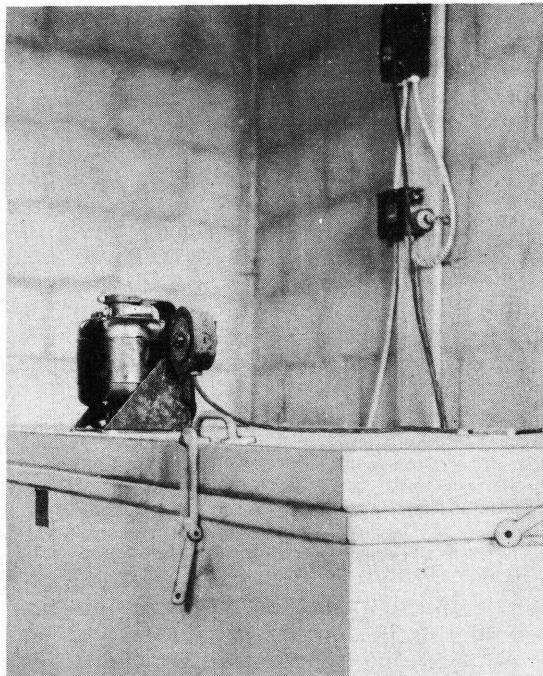


FIGURE 4.—A vertical electric motor on a storage tank for driving an agitator.

water is pumped from one storage compartment into another or from the coil compartment to the storage space. It may likewise be pumped from the bottom of the tank through a pipe placed around the top of the tank with a narrow slit or perforated openings so located as to spray cold water over the milk cans. Another method now employed is to use a small pump to force air through the water.

The air pump's intake is placed just above the water level in the tank, and its outlet is connected to perforated pipes laid along the sides of the tank. A good way to equip a home-made tank for agitation is to set up a small centrifugal pump with its intake at the bottom of the tank and its outlet at the top at the opposite end.

COILS IN STORAGE TANKS

In wet-storage tanks three systems of installing coils are used: (1) Bunched coils, made of pipe or tubing, placed in the center of the tank or along a side or end or in a corner and separated from the storage space by a baffle plate, an iron rail, or a grill (fig. 5); (2) coils

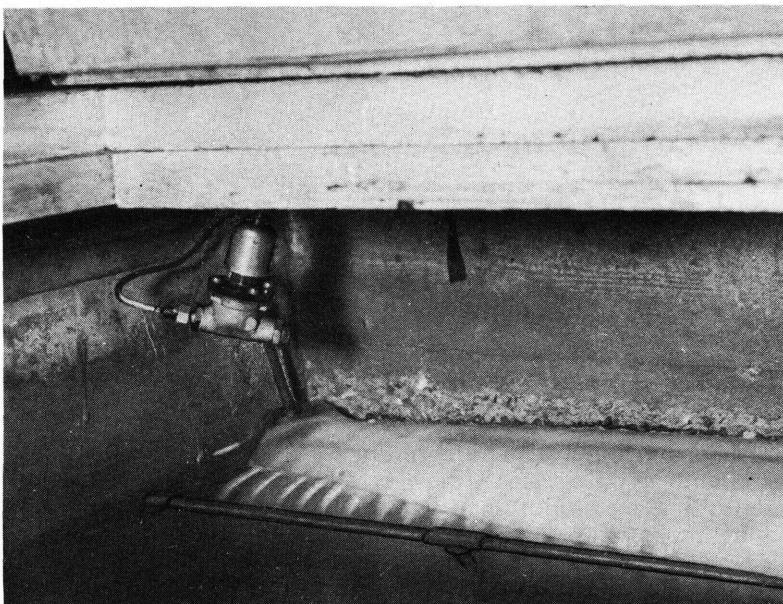


FIGURE 5.—A spiral refrigerating coil placed along one side of a tank and guarded by a pipe rail. Note the accumulation of ice on the coil.

made of pipe, tubing, or cast-iron heating radiator sections (figs. 6 and 9) arranged around the inside wall of the tank; and (3) coils made of pipe placed on the bottom of the tank. Bunched coils are sometimes difficult to support adequately, and they must be protected against being struck with the cans of milk. Also, ice accumulates more readily on bunched coils than on coils of other types, because the coils are closer to each other and generally farther from the return water of the circulating pump. Accumulations of ice as thick as shown in figure 5 are undesirable in tanks without some means of circulating the water. Where coils are placed on the bottom or around the inside walls of the tank, they should be adequately protected by a frame.

In the tanks observed the coils were almost all made of tubing of $\frac{1}{2}$ -inch inside diameter. The length of coil used per cubic foot of tank space differed greatly, and the figures given in table 3 are ap-

proximate. The proper length of cooling coil depends primarily on the design of the compressor, its operating pressures, and the refrigerant used, although it is also influenced by the temperature range through which the milk is cooled and whether the tank water is still or agitated. Since the compressor and the coils are part of the manufactured unit, the recommendation of the manufacturer for length of coils should ordinarily be accepted.

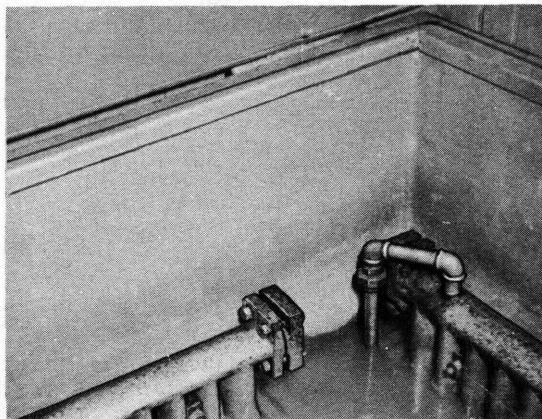


FIGURE 6.—Refrigerating coils assembled from cast-iron heating radiator sections, arranged around the inside wall of the storage tank. Copper tubing is generally used for coils.

Farmers writing to manufacturers for information regarding the selection of the proper size of refrigerating unit should give the following data: The maximum quantity of milk to be cooled and stored per 24 hours at any season; the range of temperature through which the milk is cooled (for example, from 95° to 40° F.); the temperature of the well water if well water is used; and the thickness and kind of insulation in the tank.

CARE OF STORAGE WATER

The water in tanks must be kept clean and free from objectionable odors. The care used to keep the water clean governs the length of time between changes of water. On the farms observed, the frequency of changing water in the storage tanks ranged from once a week to once in 5 months, and the length of time needed to bring the tank back to its normal storage temperature ranged from 4 to 24 hours. Where the interval between changes was 5 months, extreme care was used in cleaning the outside of the cans just before they were placed in the tank. There is a decided saving in keeping the cans clean since every time the tank water is changed the refrigerating unit must operate extra time. Where the cooling machine is working nearly at capacity, or the temperature of the clean water is high, changing water may result in inadequate cooling and storage of the milk at the next milking.

FACTORS AFFECTING THE OPERATION OF THE MACHINES

Several factors affect the reliable and efficient operation of a mechanical-cooling unit. One of the most important of these is the number of hours the compressor must operate each day to extract the necessary amount of heat from the milk through the cooling tank. If a machine runs practically all the time it may not use any more power than one running only 10 or 12 hours a day, but it will have no reserve refrigerating capacity to care for any additional milk or a spell of extremely hot weather, and a power failure or mechanical break-down even of short duration would make proper cooling impossible. If the machine is so small as to require almost continuous operation, its capacity would not be sufficient to cool the milk to below 50° F. in 1 hour unless the water to milk ratio is very high or comparatively large quantities of ice are frozen on the coils. It must be remembered that when ice surrounds the coils it acts as insulation; a large accumulation is therefore undesirable when the tank is not equipped with some means of mechanical agitation. According to tests conducted on dairy farms, described in Circular 336, under farm operating conditions the cost of cooling milk when the refrigerating unit ran from 8 to 10 hours a day was less than when it ran 14 hours or more. Then, too, small refrigerating machines are not designed for continuous operation, and the life of an overworked machine is comparatively short.

For economical cooling, the storage tank or box must be well insulated with waterproofed insulation. The general practice now is to equip tanks with 3 inches of insulation and dry boxes with 3 or 4 inches. Many home-made tanks and boxes have been equipped with 4 or 5 inches of insulation. In sections where high average daily temperatures are expected, an extra inch of insulation will more than pay for itself. In tests conducted by the Department it was found that home-made tanks were as efficient as manufactured tanks. However, all the home-made tanks contained 1 inch more of insulation than the commercial tanks.

As stated on page 7, the refrigeration loss from a well-constructed tank or box used to capacity should not be more than 30 percent. This figure includes not only the heat leakage through the walls but also losses due to handling the milk in and out of the storage. When a milk cooler is used the same figures will apply.

Precooling milk over a cooler has the advantage of lowering the temperature of the milk quickly below 50° F., and where cold well or spring water is used through part or all of the cooler such precooling reduces the refrigeration load and consequently the cost of cooling. The amount of heat that can be removed by running the milk over a cooler depends on the temperature of the cooling medium run through the cooler coils, the amount per minute, and the speed at which the milk flows over the cooler. The difference between the temperature of the cooling medium and the milk after the cooling operation was found to vary from about 1° to 10° F., and averaged 3°. If 60° water is run through the coils of a milk cooler and the milk is allowed to pass over its surface in a thin solid stream it would be cooled to about 63°. Thus if the milk is to be cooled to 40° it would be necessary to lower its temperature 23° additional by refrigeration.

Milk coolers can be piped to use well or spring water alone, well or spring water through the top half and tank water or brine through the lower half (fig. 7), and tank water or brine through the entire cooler (fig. 8). The method used depends on the way the milk is handled and the availability of water. If water is scarce or has to be pumped against a high head it may be least expensive to pump tank water or brine through a cooler. Where the morning's milk is to be shipped without any storage it is necessary to use tank water or brine through half or all the cooler to reduce the temperature of the milk sufficiently to have it reach the market in good condition. Regard-

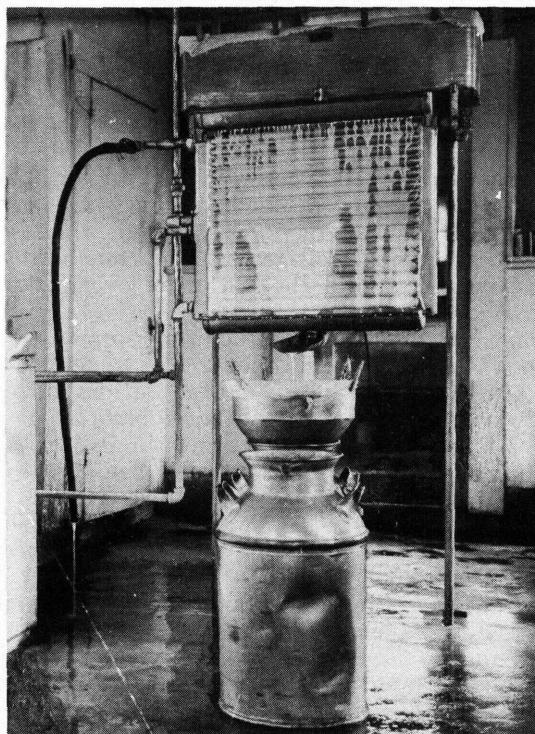


FIGURE 7.—Milk cooler piped to run tap water through the top half and tank water through the bottom half.

less of what cooling medium is used, the cooler should be piped so that the cold medium enters the bottom of the cooler and leaves the top. This insures that the milk will pass over the coldest part of the cooler last and gives the greatest amount of cooling. The tap water used in the top half of the cooler shown in figure 7 leaves the top of the cooler through a short piece of hose and is wasted on the floor.

Dry-box storage has been found to require more power per gallon cooled than wet-tank storage and is seldom used to cool bulk milk. It is satisfactory for such use only when the milk is first cooled over a milk cooler. One big advantage of this system is that because of the use of a brine or direct-expansion milk cooler the milk can be cooled to a lower temperature in a shorter time.

PLANS FOR STORAGE TANK AND BOX

The drawings shown in figure 9 give detailed plans for the construction of an insulated concrete storage tank with an insulated wood cover.⁴ Several different kinds of insulation, loose or in waterproof packages, may be used. Corkboard has been the most popular. Regardless of the insulation used, it must be covered thoroughly with asphalt to keep out moisture. The insulating value of any material is greatly decreased if it becomes wet. The bottom of the tank may be made smooth instead of ridged as shown, but in that case the cans should be set on a grating made of water-resisting wood or a sheet of galvanized corrugated metal, to permit the circulation of water under the cans. The number and size of the coils and the size of the compressor unit depend on the maximum quantity of milk to be cooled daily and the number of degrees through which the milk is to be cooled (table 4).

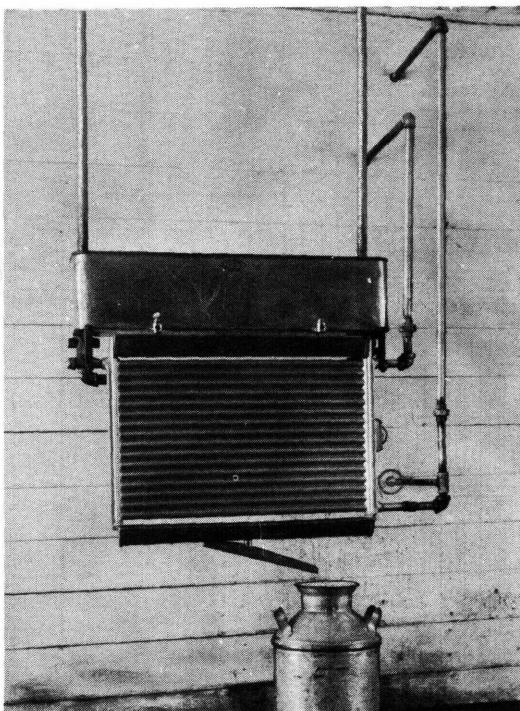


FIGURE 8.—Milk cooler piped to run brine through the entire cooler.

The small dry box shown in figure 10 has been designed primarily for use on farms where the milk is bottled. If the milk is to be stored in cans, the box will take care of a much larger quantity of milk than if it were stored in bottles, and care should be taken to have a compressor and a brine tank large enough to supply the total amount of refrigeration in 10 or 12 hours and to cool the milk to the desired storage temperature in the time that it is allowed to run over the surface cooler.

⁴ Directions for making concrete are contained in Farmers' Bulletin 1772, Use of Concrete on the Farm.

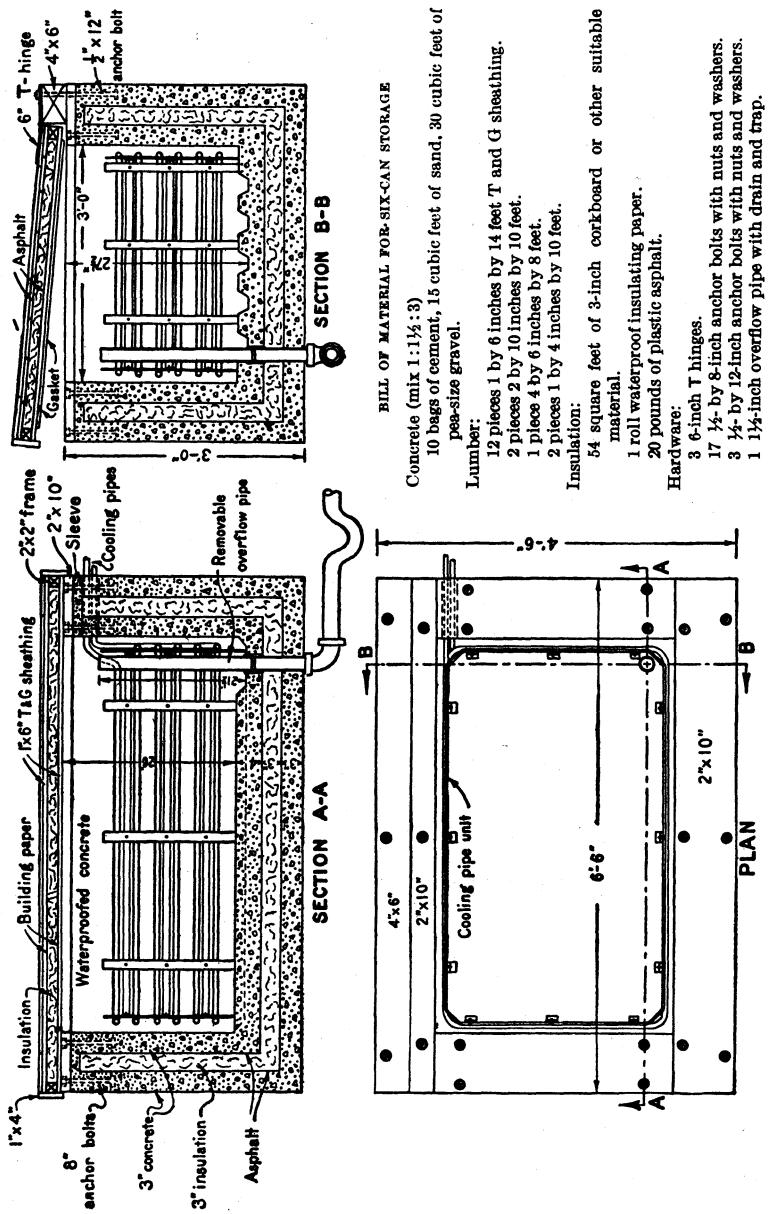
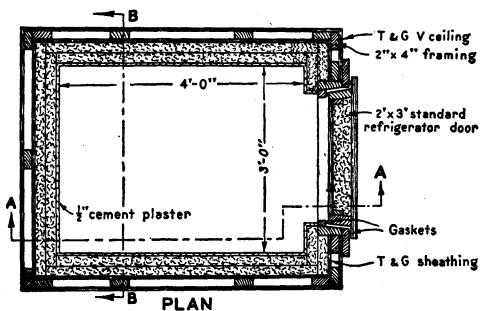
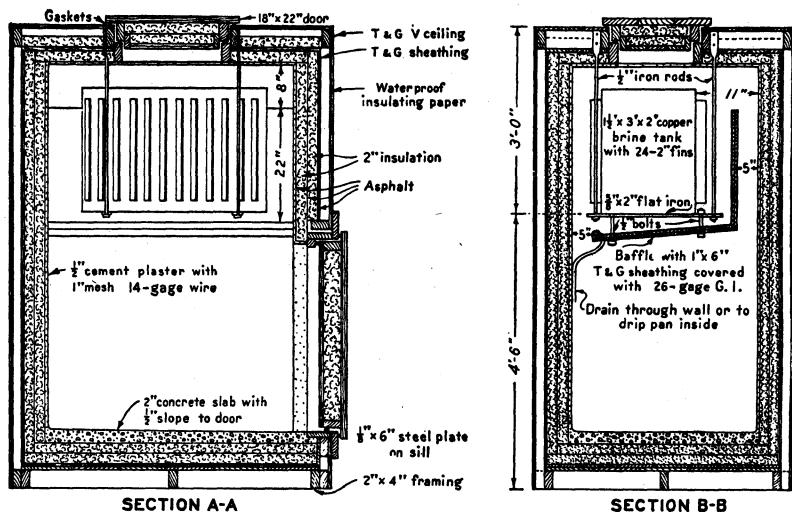


FIGURE 9.—Plan for constructing a storage tank.

Dry-box storage is not recommended for cooling milk. It is used only as a low-temperature storage place for the milk which has been previously cooled.

Figure 11 shows a plan for a walk-in storage box, and gives an alternate design of wall construction to be used with fill insulation. Fill insulation is generally available in many forms, may cost less, and is as efficient as rigid insulation when properly installed. However, great care must be exercised in applying the waterproof insulating paper outside the fill to form a complete vapor seal. The paper should be folded into corners where feasible rather than being cut-in. In the case of doorways where cutting is imperative the joints should be covered with an extra layer of paper after being coated with asphalt. Since the efficiency of the insulation is lowered by the absorption of moisture, this care is necessary to keep the warm moisture-laden air from seeping into the fill compartment, where it is chilled by the cold wall next the refrigerated room and some of its moisture is deposited on the insulation.

The drawings show the inside walls of the box finished with cement plaster. If desired, wood sheathing may be placed inside of the insulation and covered with 26-gage galvanized iron. All joints must be soldered. A direct-expansion coil can be substituted for the brine tank in the storage box, if a direct-expansion milk cooler is to be used.



BILL OF MATERIAL FOR STORAGE OF 50 GALLONS IN QUART BOTTLES

Concrete (mix 1: 1½ : 3)
1 bag cement, 1½ cubic feet sand, 3 cubic feet gravel.

Plaster:
3 bags cement, 4 cubic feet sand.

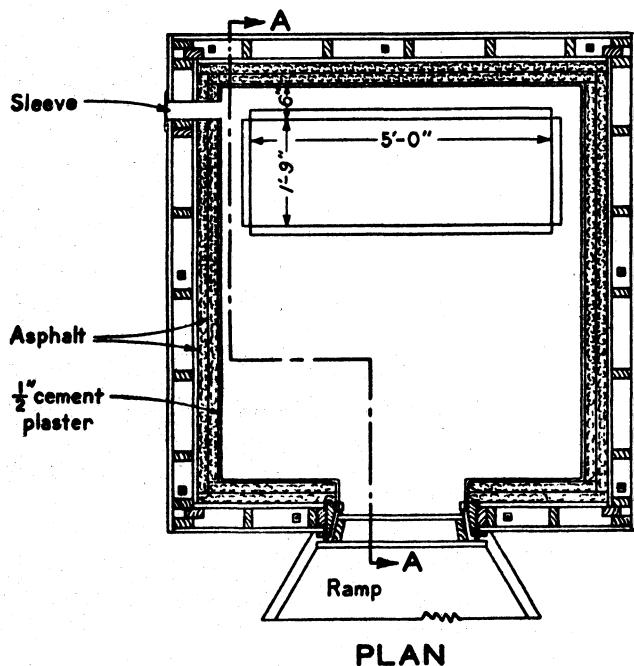
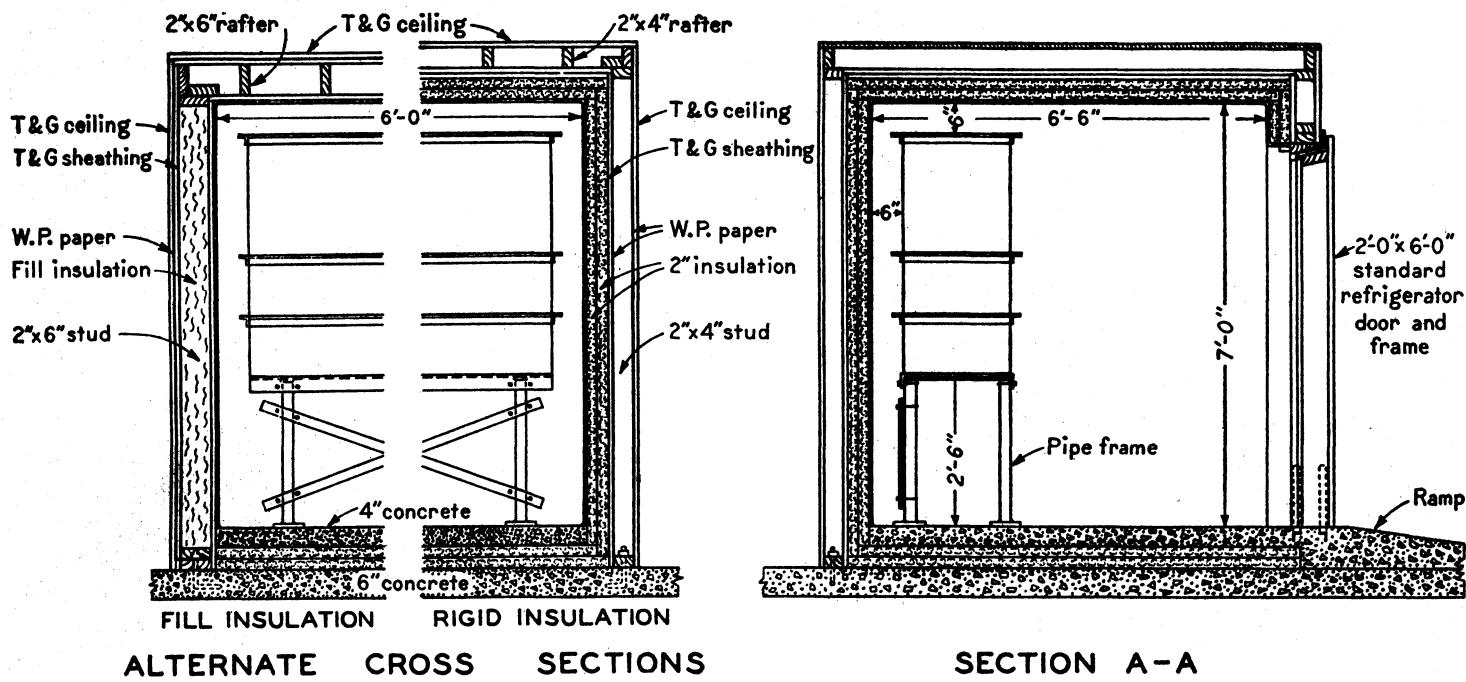
Lumber:
250 board feet, 1- by 6-inch T. and G. sheathing.
200 board feet, tongue-and-groove V-ceiling.
15 pieces 2 by 4 inches by 8 feet.
15 pieces 2 by 4 inches by 10 feet.

Miscellaneous:
50 pounds of plastic asphalt.
250 square feet of 2-inch corkboard or other suitable insulating material.

2 rolls waterproof insulating paper.
1 2- by 3-foot standard refrigerator door and equipment.
4½- by 40-inch iron rods, threaded on one end.
2½- by 8-inch machine bolts, with nuts and washers.
4½- by 2-inch iron flats, 26 inches long.
20 square feet 26-gage galvanized iron.
1¾-inch drain pipe, length as required.

FIGURE 10.—Plans for constructing a storage box.

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**BILL OF MATERIALS FOR WALK-IN STORAGE
BOX FOR 400 QUARTS OF MILK IN BOTTLES
INSULATED WITH RIGID INSULATION.**

Concrete (mix 1 : 1½ : 3):

5 bags cement, 8 cubic feet sand, 15 cubic feet gravel.

Plaster:

7 bags cement, 8 cubic feet sand.

Lumber:

450 board feet 1- by 6-inch tongue and groove sheathing.

400 board feet tongue and groove ceiling.

55 pieces 2 by 4 inches by 8 feet.

Miscellaneous:

100 pounds plastic asphalt.

675 square feet of 2-inch corkboard or other suitable insulation.

4 rolls waterproof insulating paper.

1 2- by 6-foot standard refrigerator door with frame and equipment.

4 pieces 2-inch pipe 30 inches long.

4 6-inch floor flanges for 2-inch pipe.

14 feet 3- by 3- by ¼-inch angle iron.

12 feet ½- by 2-inch flat iron.

12 ¾-inch U-bolts for 2-inch pipe.

1 5-foot by 1 ½- by 4-foot brine tank.

9 ¾- by 6-inch anchor bolts.

FIGURE 11.—Plans for walk-in storage box.

